SOME EAST AUSTRALIAN SEA-GRASS COMMUNITIES.

By E. J. Ferguson Wood.*

(Two Text-figures.)

[Read 24th June, 1959.]

Synopsis

The common sea-grasses in the estuaries of south-east Australia are *Posidonia* spp (probably two species), *Ruppia maritima, Halophila ovalis, Zostera capricorni, Z. muelleri,* and *Z. tasmanica.* In *Z. muelleri* there are fewer anthers than in the other two species, which may be distinguished by the spathes.

In the estuarine environment, *Ruppia* grows in water of lower salinity than the other grasses, *Halophila* grows in deep, muddy water, but may be found growing sparsely in the shallows, *Posidonia* normally grows on sandy slopes, but may occur in shallow waters, while *Zostera* grows best on shallow flats with a mud bottom, though the mud may be overlain by sand. *Z. muelleri* grows near the shore, in shallow water, from Queensland into eastern Victoria and possibly further west, *Z. capricorni* grows from about Noosa in Queensland to Lake Tuross in New South Wales, and *Z. tasmanica* from Tuross south.

Swans cause great depredations on *Zostera* beds by digging up and eating the stolons and young shoots; these depredations may be semi-permanent or permanent, depending on the water movement over the flats.

Introduction.

The taxonomy of Australian sea-grasses has been dealt with by several workers, but no ecological studies have been made. This paper deals briefly with the taxonomy of the common sea-grasses of south-east Australia and records field observations. Numerous attempts have been made to cultivate *Zostera* and *Posidonia* under aquarium conditions. Even with the simulation of natural conditions, including tidal action, the plants have not lived for more than a few months. Sections of the bottom with the plants undisturbed were transferred to plastic tanks in running water, but even under those conditions the plants grew for only three months, flowered, and died. They did not regenerate from the stolons nor did the seeds mature. Owing to these failures, it has not been possible to confirm field observations by laboratory experiment.

Previous Studies.

Bentham (1877) listed from Australia 7 genera of marine grasses, including the following species: *Ruppia maritima* L., *Posidonia australis* Hook., *Zostera nana* Roth., *Z. tasmanica* G. v. Mart., *Cymadocea antarctica* (Labill.) Endl., *C. ciliata* (Forsk.) Ehr., *C. serrulata* Aschers., *C. isoetifolia* Aschers., *Lepilaena australis* Drumm., *L. cylindrocarpa* Benth., *L. preissi* F. Muell., *Naias major* All., *N. tenuifolia* R. Brown, *Halophila ovalis* Hook., and *H. spinulosa* Benth. None of Bentham's records were from New South Wales.

Ostenfeld (1929) gave a more recent list, and some further localities. He listed *Cymadocea angustata* Ost., *C. antarctica* (Labill.) Endl., *C. ciliata* (Forsk.) Ehr., *C. isoetifolia* Aschers., *C. rotundata*? (Ehr.) Aschers. and Schweinf., *C. serrulata* (R. Br.) Aschers., *Diplanthera uninervis* (Forsk.), all from Western Australia or Queensland; *Posidonia australis* Hook. from southern Tasmania, and Western Australia north to Carnarvon; *Zostera capricorni* Aschers. from Queensland, Port Jackson, Long Reef, Botany Bay, and Harwood Island in New South Wales; and *Z. muelleri* Irmisch from Port Phillip and Point Lonsdale in Victoria, Victor Harbour and Port Pirie in South Australia, Tasman Peninsula, D'Entrecasteaux Channel, Port Esperance, and Southport in Tasmania. *Halophila decipiens* Ost. is recorded from Sydney Harbour; *H. ovalis*

---

* Division of Fisheries and Oceanography, C.S.I.R.O., Cronulla, Sydney, Australia.

(R. Br.) Hook. from Port Jackson in New South Wales, Pialba to Cape York in Queensland, Geraldton, Swan River, and Rottnest Island in Western Australia, Victoria, and Tasmania; and *H. spinulosa* (R. Br.) Aschers. from Pialba and Moreton Bay in Queensland.

Thalassia hemprichi (Ehr.) Aschers. was collected from Port Dennison and Murray Island in Queensland, and *Enhalus acroides* (L. fil.) Steud. from Thursday Island and Cape York.

TAXONOMY.

Genus HALOPHILA Thou.

Submerged marine herbs. Flowers unisexual, solitary, within a pair of herbaceous bracts. Male flower: perianth of 3 segments; 3 anthers, sessile, alternating with segments, erect, two-celled, cells opening outward; pollen confervoid. Female flowers: no perianth, single ovary tapering into a filiform style with a short stigma, either single or divided into 3 to 5 filiform segments. Several ovules, erect, attached to sides of cavity. Fruits membranous, opening irregularly. Seeds nearly globular, with thin testa, rather loose. Embryo erect with thick radicular base nearly the shape of the seed, distinct plumula and an involute or spiral cotyledonous end, both nearly immersed in a terminal groove. Leaves in pairs, apparently opposite, sessile or petiolate, the petioles frequently enclosed at base in 2 broad, scarious, white or hyaline scales. Floral bracts axillary, sessile, or males pedicillate.

Bentham states (1877, p. 182) that the genus is confined to the Indian and West Pacific Oceans and the Mediterranean Sea. *H. ovalis* is the common species of the genus in the environment considered in this paper.

HALOPHILA OVALIS Hooker.

Stems creeping and rooting under water, emitting at each node 2 broad, thin, colourless, hyaline scales 2 or 3 lines in diameter. Within these scales lie a pair of leaves with long slender petioles and a herbaceous lamina varying from oval and less than half an inch long to oblong-elliptical and 2 to 2½ in. long, very thin, penniveined, with a broad central nerve and very fine lateral, oblique veins; margin quite entire. Involucres or double spathes enclosing flowers ovate, sessile within scales. Male flowers on pedicel emerging from involucre, females sessile within it.

Genus RUPPIA L.

Normally subsaline aquatic plant with slender, much-branched stems, and linear-filiform leaves. Flowers hermaphrodite, in a spike enclosed when young in the sheathing bases of the floral leaves. Perianth absent. Anthers 2, each with 2 distinct cells (described sometimes as 4 one-celled anthers), the cells opening outwards. Pollen grains narrow-oblong. slightly curved with ends somewhat dilated. Four carpels, at first sessile, but soon protruded on long stalks, each with a pendulous ovule and terminating in a short style or broad, almost sessile, stigma. Fruiting carpels ovoid or pear-shaped, often oblique, obtuse or more or less produced into a slightly curved beak.

Bentham (1877), from whom the above description was taken, considers that there is only one species which exhibits considerable variation, but not in diagnostic characters. The material collected during the present investigation agrees closely with his description of *R. maritima*.

RUPPIA MARITIMA L.

Stems and leaves submerged, filiform, the leaves often very long; barren leaves alternate, slightly dilated at base. Leaves crowded in a tuft, dilated at base into thin, almost scarious sheaths, closely imbricate and completely enclosing the young spike, which soon emerges on a (short or long) spirally coiled pedicel, bringing it to the surface of the water. Flowers 2–6, sessile, at first close together, later often distant. Anthers less than half line long. Carpels at the time of flowering are not exceeding anthers, but immediately after flowering anthers fall away, and stalks of carpels lengthen by as much as half an inch to an inch or more. Ripe carpels one line or more in length.

Genus Posidonia König.

Marine submerged plants. Flowers hermaphrodite, or the terminal one of each spike male or semi-abortive. Perianth absent. Anthers 3 to 6, consisting of a broad, almost fleshy connective, with 2 short dorsal cells at base, separated by the broad, thick centre. Ovary of one sessile carpel, with 1 erect ovule, terminating in 2, 3, or more short stigmatic lobes. Fruit indehiscent, the pericarp thick and fleshy or succulent. Seed adnate to one side of cavity; embryo erect, straight, with a rather large plumule in a terminal groove. The base of the stem is covered with filamentous remains of old leaf-sheaths. Leaves often very long, breaking off transversely from the persistent sheathing base. Scape leafless below inflorescence, bearing at end several spikes, each in axis of a short, floral leaf, the peduncle enclosed at the base of 2 sheathing bracts, each flower subtended by a small bract and two bracteoles.

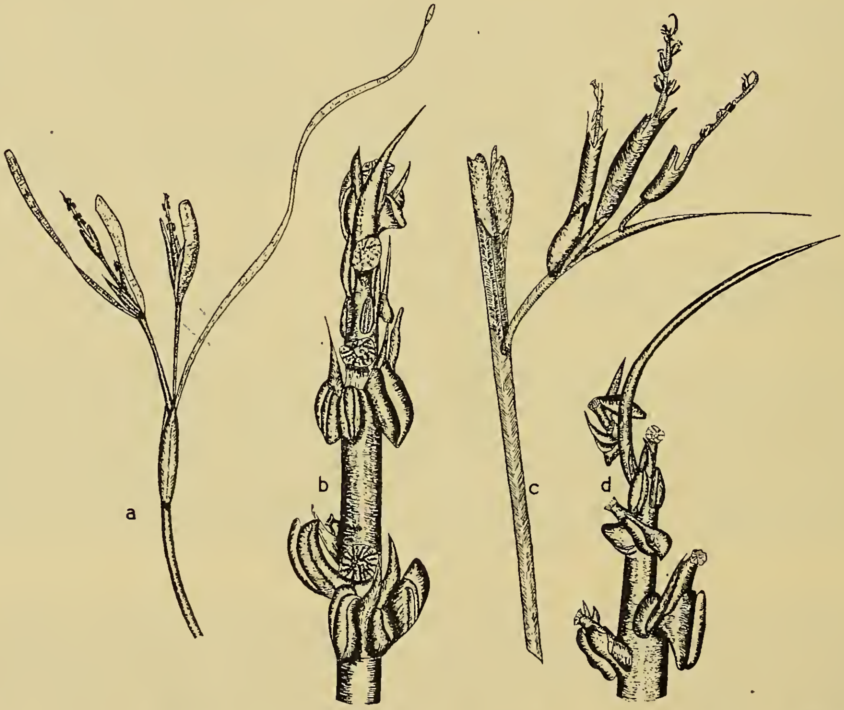


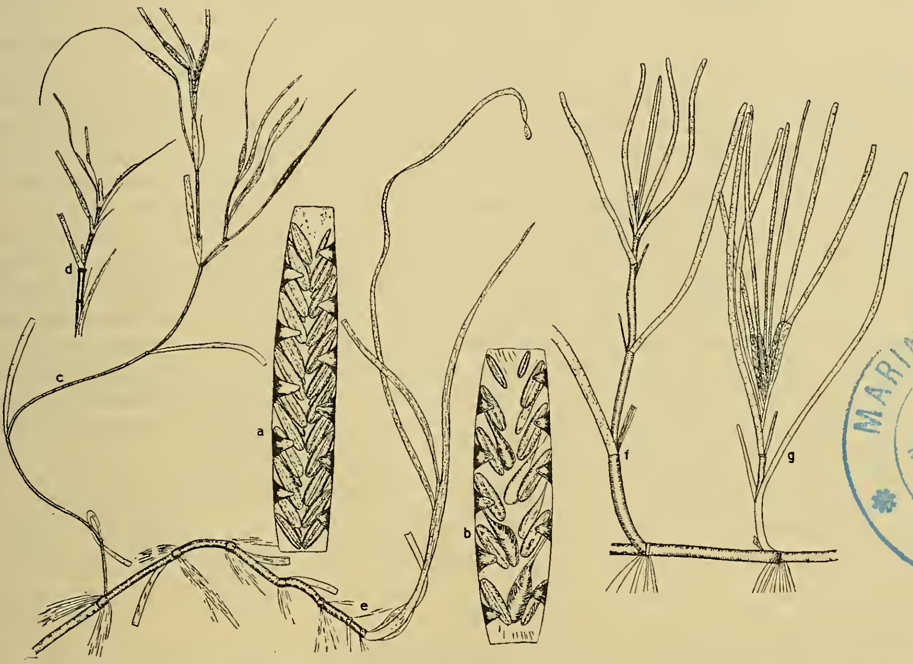
Fig. 1.—Floral differences in *Posidonia*: *a*, Merimbula form—showing arrangement of anthers, and *b*, showing fertile shoot. *c*, Port Hacking form—showing arrangement of anthers, and *d*, showing fertile shoot. Drawn by L. Crosby.

The genus is at present being revised by Dr. Melville at Kew, but there appear to be two forms on the east Australian coast, one collected from Merimbula and having 6 anthers per pistil and a long slender leaf (Fig. 1, *a* and *b*), the other from Port Hacking, having 3 anthers and a shorter thicker leaf (Fig. 1, *c* and *d*). The arrangement of the spadices is also somewhat different as the figures show.

Genus Zostera L.

Marine submerged plants. Flowers unisexual, males and females in alternate rows on the membranous rachis of the spike enclosed in the sheathing base of the floral leaf. Perianth absent. Male flowers of a single, ovate, laterally attached, one-celled anther;

pollen confervoid. Female flowers of a single carpel, gourd-shaped, laterally attached near apex, and produced above attachment into a filiform two-branched style. Fruit an indehiscent nutlet. Embryo with deep, longitudinal groove forming 2 valves which fold over the long, curved, linear cotyledonous end. Creeping rhizome, emitting short stems with long, narrow, grass-like leaves separated from their narrow sheathing bases by a transverse line. Peduncles axillary or terminal, bearing a single spike completely enclosed in the more or less dilated but continuous sheathing base of the floral leaf or spathe, which otherwise resembles the stem-leaves. Rachis of spike broad and thin, with margins folded inward and bearing flowers and fruits only on inner surface.



MARINE
MASS.
RATORY

Fig. 2.—Differences of *Zostera* species: a, Anthers of *Z. capricorni* (*Z. tasmanica* is similar); *b*, Anthers of *Z. muelleri*; *c*, Fertile shoot of *Z. capricorni*; *d*, Fertile shoot of *Z. muelleri*; *e*, Sterile shoot of *Z. capricorni*; *f*, Sterile shoot of *Z. muelleri*; *g*, Fertile shoot of *Z. tasmanica*. Drawn by L. Crosby.

Setchell (1933) divided *Zostera* into 3 sections, *Alega*, which has not been recorded from the Southern Hemisphere, *Zosterella* and *Heterozostera*, both of which have southern representatives. He points out that there is considerable confusion with regard to the type material from Australia and New Zealand.

There appear to be three species of *Zostera* represented in east Australian waters corresponding to *Z. capricorni* Ascherson, *Z. muelleri* Irmisch (both in the *Zosterella* section) and *Z. tasmanica* (*Heterozostera*).

Setchell divides these species on the leaf venation, shape of leaf apex and the retinacula (bracts ? arising within the elevated margin of the spathe), though the *Heterozostera* section has other characteristics. However, the examination of several hundred specimens shows considerable variation in the shape of the leaf apex and in the leaf venation, thus reducing the usefulness of these criteria for diagnosis of the species concerned. This variation can be discerned in leaves from one bed, and even from individual plants. Examination of material collected from various parts of Port Hacking, Lake Macquarie and Lake Illawarra showed that in *Zostera capricorni*, 20 per cent. of the uninjured leaf tips were evenly rounded, 23 per cent. regularly truncate, 15 per cent. irregularly truncate, and 42 per cent. regularly or irregularly notched. In *Z. muelleri*, 15 per cent. were evenly rounded, 27 per cent. regularly and 13 per cent. irregularly, truncate, while 45 per cent. were notched. The denticulation of the leaf tips also varied considerably; this may be due to injury rather than to specific differences, especially as the majority of leaves examined had obviously been damaged, the whole tip being missing.

However, a separation of the species can be made using the number and arrangement of the anthers. In *Z. tasmanica* and *Z. capricorni*, the anthers are arranged in two closely packed rows (Fig. 2, *a*), while in *Z. muelleri* they are alternate and somewhat spaced (Fig. 2, *b*). *Z. tasmanica* has 20–24 anthers per inflorescence, *Z. capricorni* 13–20, and *Z. muelleri* 10–11. The length of the fertile shoot is not very useful for separating *Z. muelleri* from *Z. capricorni*, as both are long relative to the plant (Fig. 2, *c* and *d*). *Z. muelleri* can be distinguished in the field from *Z. capricorni* by the fact that the leaves of the former are smaller and narrower. A sample from Lake Macquarie of 300 leaves of each species gave mean dimensions of: *Z. muelleri*, 30 × 2 mm., and *Z. capricorni*, 55 × 4·5 mm., though many samples of the latter from other areas would have a far greater length, and leaves up to 1 metre long have been observed at Stewart's Point, Crookhaven and other places. *Zosterella* and *Heterozostera* are separated by the situation of the stem bundles and fibre strands, and by the stem and spathes. In *Zosterella* the rhizomes have one lateral bundle on each flank and fibre strands in the inner portion of the cortical layer, the stems are horizontal, with very short vertical branches, and the spathes are very slightly swollen but conspicuous. In *Heterozostera*, i.e., in *Z. tasmanica*, there are multiple vascular bundles in the internodes, the fibre strands are just beneath the epidermis, the vertical stems are often long (up to 30 cm.), and the spathes markedly swollen, and sessile, being almost or quite shielded by the sheath of the leaf below (Fig. 2, *g*). The floral branches of the *Heterozostera* are very hard to find in the field (cf. Fig. 2, *f* and *g*), whereas the long, well differentiated, fertile branches of the *Zosterella* section are easy to see (Fig. 2, *c*, *d*, *e*).

The differences between the three Australian species are summarized thus:

Z. muelleri.	*Z. capricorni.*	*Z. tasmanica.*
Anthers 10-11, alternate.	Anthers 13-20, in 2 packed rows.	Anthers 20-24, in 2 packed rows.
Leaves up to *c.* 30 × 2 mm.	Leaves from 45-100 × 4·5 mm.	Leaves from 45-100 × 5 mm.
One lateral bundle on each side of internode.	One lateral bundle on each side of internode.	Multiple bundles in internodes.
Fibres in inner cortex.	Fibres in inner cortex.	Fibres near epidermis.
Spathe obvious, not swollen.	Spathe obvious, not swollen.	Spathe inconspicuous, swollen.
Fertile stem longer than barren stem.	Fertile stem longer than barren stem.	Fertile stem similar to barren stem.

ECOLOGICAL RELATIONSHIPS.

Because the east coast of Australia is characterized by a large number of shallow coastal lagoons and meandering river estuaries, the sea-grass associations become ecologically and economically important. Within the estuaries they form large areas which are associated with inshore fisheries and oyster culture. They occur in microbiologically active areas, the roots being in reducing zones while the leaves are in oxidized water which, under active photosynthesis, is oxygen-saturated.

The grasses found on the east coast are, in rising order of importance, *Halophila*, *Ruppia*, *Posidonia* and *Zostera*. *Cymadocea*, which occurs in large beds, and washes ashore to form banks up to 6 feet deep and many feet wide in the Bunbury-Busselton area of Western Australia, is unimportant on the east coast.

(*a*) *Halophila.*

Halophila is relatively unimportant in the estuaries of eastern Australia, except in some relatively deep, still, muddy areas, often below 20 ft., such as Bundabah (Port

Stephens), Merimbula Lake, and deeper parts of Lake Macquarie. In these places it is usually dominant or associated with red algae such as *Gracilaria* sp. Where it occurs in shallow water it is sparse to subdominant, e.g., Little Swan Bay (Port Stephens) and Gunnamatta flats (Port Hacking). It is then associated with *Zostera* or, less often, *Posidonia*, together with numerous red algae such as *Gracilaria*, *Laurencia*, *Gigartina*, *Polysiphonia* and *Ceramium*, and the brown *Ectocarpus*. *Halophila* appears to be associated with reduced, sulphide-containing muds. The Lake Macquarie muds where *Halophila* was found had Eh values of –50 to –100 mV, and the same limits were observed in the *Halophila* regions in Port Hacking. While *Halophila* is usually found in areas of lower chlorinity, from 18 to 19·0‰, it can also occur, as it does in Port Hacking, in water of normal chlorinity, from 19·5 to 20‰. Illumination in the deeper regions of growth was of the order of 5 to 10 per cent. of surface values.

(*b*) *Ruppia.*

Ruppia, often called "swan grass", is usually associated in the east coast estuaries, with water of lower chlorinity, from about 16‰ as in Swan Bay (Port Stephens) to almost potable water, as at Killarney (George's Basin) and upper Lake Conjola. In these cases it is dominant. In other cases, e.g., Galgabba Flats in Lake Macquarie and at the western end of Merimbula Lake, *Ruppia* is associated with *Zostera* where the chlorinity is 17·5–19·5‰. On Galgabba flats and Lake Erraring, in Lake Macquarie, *Zostera* was dominant until a large flock of swans invaded the area and removed most of the *Zostera*, leaving the *Ruppia*. (In both Merimbula and Lake Macquarie, heavy freshes may cause stratification and a temporary lowering of the chlorinity to about 5‰ which may favour the growth of *Ruppia*.) The Eh of the muds on which *Ruppia* grows is usually negative, though at Killarney the surface was oxidized, but a very strong sulphate reduction was going on a centimetre below. *Ruppia* normally has few epiphytes, although at times it does become covered with a mat of *Ectocarpus*, or filamentous blue-green algae, diatoms (chiefly *Synedra ulna*) being relatively sparse. *Ruppia* flowers in the summer, from November through to February, but seedlings have been observed only at a lagoon near Shell Harbour, New South Wales, and at Paynesville in Gippsland, Victoria. *Ruppia* has not been found in water much more than 6 feet deep at mean low water, and appears to require good illumination, and little current.

(*c*) *Posidonia.*

More than one species of *Posidonia* has been recognized in Australian waters, but the taxonomy of the genus is still doubtful. *Posidonia* has its greatest development in the South Australian gulfs and on the west coast of that State. There, the growth is so abundant that numerous attempts have been made to use the fibre commercially (Winterbottom, 1917). On the east coast of Australia, however, *Posidonia* is of interest merely as forming a community in the sea-grass association, where it normally occurs in waters from about 6 feet below mean low water to between 20 and 30 feet. Here it is characteristic of sloping, sandy shores, where the bottom has a positive Eh extending for several centimetres in depth, the water is clear, and turbidity slight, e.g., in Lake Macquarie, Cabbage Tree (Port Hacking), Weeney and Quibray Bays, and on the northern slope of Towra Point in Botany Bay. At Merimbula, the *Posidonia* occurs as the dominant form on shallow tidal flats between the causeway and the entrance to Merimbula Lake where the Eh is about +250mV. At times it is found associated with *Zostera*, e.g., on the Belmont flats (Lake Macquarie), and with *Zostera* and *Ruppia*, e.g., in the shallows of Merimbula Lake. In such cases it does not appear very healthy. *Posidonia* has not been found in exposed waters on the east coast.

Posidonia usually has a number of epiphytes on the leaves, e.g., diatoms, red algae (*Melobesia*, *Ceramium*, *Polysiphonia*, *Laurencia*), brown algae (*Ectocarpus*, *Colpomenia*), the green algae (*Vaucheria*, *Enteromorpha* and *Chaetomorpha*), and blue-green algae (*Oscillatoria*, *Lyngbya*). In addition, the ciliate, *Vorticella*, the tube-worm, *Spirorbis*, and encrusting bryozoa are numerous. The epiphytic diatoms are less important than on the adjacent *Zostera* but, in general, the same species occur and consist of stipitate forms including *Licmorphora, Navicula, Skeletonema, Plagiogramma, Melosira, Grammatophora, Cocconeis* and *Amphipleura.*

Though *Posidonia* is normally the dominant form, the community usually contains a number of algae, including *Sargassum, Gigartina, Gracilaria,* and a very large number of species of red algae, *Dictyota,* often *Cystophyllum* (at Wallis Lake), *Codium tomentosum* and *C. lucasi,* various Caulerpas.

The leaves of *Posidonia* contain a nitrogen-containing reducing substance, volatile in steam, which reduces cadmium or lead acetate to the metal, but differs in odour from that contained in *Zostera* (Wood, 1953).

(*d*) *Zostera.*

Of the sea-grass communities, the *Zostera* community is most important both ecologically and commercially. In Europe, Japan, America and Australia, this plant is associated with the growth of crustacea and other larvae, oysters, and other molluscs, and is of general occurrence in estuaries in temperate waters. The "wasting disease" of this plant in Europe and America, and the consequent failure of various fisheries in these countries, showed how close the relation was between the plant and the animal life of the estuary (Renn, 1936).

Zostera grows in water which is marine in character, and has a chlorinity of the order of 18–19‰, though it may, at times, encroach into less saline waters. It grows from low tide mark to a depth of about 20 feet and appears to require good illumination, as it does not do well in turbid water. The depth to which it grows seems to depend on turbidity. The grass can persist in the presence of currents of several knots, as in the channel entrances to Lake Macquarie and Sussex Inlet. *Zostera* has been found growing on bottoms with Eh values of +180 (Lake Macquarie, in gravel) to –150 mV (Maianbar, in sand and reduced with abundant H_2S (0·2n)), and where the pH varies between 5·5 in the mud to 9·3 in the water on sunny days near midday.

The plants have been found with their root hairs in actual contact with particles of hydrotroilite (FeSH(OH)). *Zostera* normally has its root system in a reducing environment and produces organic reducing substances (Wood, 1953); it seems probable that its metabolism is adapted to such environments. The reducing substances occur in the epidermis of the leaves and stolon, and in the leaf gland cells. They are associated with a pigment which is possibly a digalloyl.

The *Zostera* community is rich with plant and animal life. The microbial groups in the mud consist of bacteria of the sulphur cycle, including *Desulphovibrio, Thiobacillus* sp., *Th. denitrificans, Chromatium, Chlorobium,* large numbers of heterotrophs, including anaerobes, a few naviculoid diatoms, flagellates, and ciliates, including anaerobic *Colpidium, Euplotes,* and rhizopods. The epiphytes are very numerous and include a very large assemblage of diatoms, *Ectocarpus, Ceramium, Polysiphonia, Oscillatoria, Lyngbya,* and other blue-green algae, while the protozoan *Vorticella,* and the serpulid *Spirorbis* are common, e.g., in the channel at Lake Macquarie. The epiphytes serve as food for mullets and other phytophagous fish, the gastropod *Pyrazus* etc., and the *Zostera* itself is consumed, and apparently digested, by the nudibranch *Aplysia,* and the garfish (*Reporhampus ardelio*).

Zostera flowers and fruits in the summer, from November to the end of March, and flowering occurs in patches, at times small and localized, and at times large and widespread. Although a careful watch was kept for several years, no seeds or juvenile plants were observed except at Paynesville in Victoria, hence it would appear that propagation is very largely vegetative. *Zostera muelleri* occurs mainly in shallow water (low water line to about 5 feet) and *Z. capricorni* in deeper water (from 2 feet below low water to below 20 feet). However, the two species may be interspersed. Soon after flowering, most or all of the aerial shoots die off, and only the stolons, which are subterranean, and a few residual shoots or stools remain. Thus, in autumn, a *Zostera* flat may seem completely bare of weed. The dead leaves either wash out into deeper water or ashore, where they form high banks which rot slowly. Cellulose digestion of the cell walls is very slow, and no cellulose digesting bacteria were isolated from Lake Macquarie. However, Imai *et al.* (1951) have shown that the decaying *Zostera* serves to harbour and nourish a number of microorganisms including heterotrophic bacteria and colourless flagellates. These authors found that, in Japanese waters, one of these flagellates, *Monas* sp., serves as the food of the larval oyster (*Ostrea gigas*), and that the spawning of this oyster coincides with the death of the *Zostera* in Matsushima Bay and Mangoku Inlet. The spawning of the Australian oyster has not been definitely correlated with the death of *Zostera*, but occurs between December and March when the *Zostera* is declining, so the same relation may hold in Australian estuaries. Living *Zostera* harbours a number of microplankton and phytoplankton as well as zooplankton organisms and small fish. Diatoms such as *Coscinodiscus*, *Biddulphia*, and dinoflagellates such as *Exuviaella*, *Gymnodinium*, *Prorocentrum*, are common in the community, and so are various crustaceans, e.g., Copepods, Mysids, Caprellids, which, no doubt, attract the fish into the community, where they also find shelter from their enemies.

Swans may cause great depredations in the *Zostera* beds. In the cases observed large areas were denuded, and this may be assumed to have had repercussions on the fishing potential of the areas. Swan faeces were examined and found to consist entirely of *Zostera*, mainly stolons, the leaves being torn off and allowed to float away. Another effect of this denudation by swans is that the bottom is no longer held in place by the *Zostera* stolons, and may be moved about by currents and winds, thus becoming oxidized and so unfit for future growth of the plant. This has happened over a large portion of the Goodwin Sands, Mallacoota, on the "proclaimed" areas of Lake Illawarra and in Lake Erraring, an offshoot of Lake Macquarie.

The larger organisms associated with *Zostera* include a number of algae, e.g., *Enteromorpha prolifera*, *Chaetomorpha*, *Microdictyon*, *Colpomenia*, *Cystophyllum*, *Codium*, *Caulerpa*, *Dictyota*, etc., and some of these during spring or autumn may form a felt which covers the *Zostera*, and may produce anaerobiosis below it. With these felts are *Ectocarpus*, various filamentous red algae, and diatoms, as well as the microplankton. Such felts at last float off and may cause a nuisance on the estuary or on the beaches, and by fouling nets and lines, making it impossible to fish.

In the Gippsland Lakes, the *Zostera* beds are said to have been denuded by crabs which invaded the lakes after the opening of the entrance, but it is difficult to know at this stage whether the crabs, or changes in lake level and salinity due to deforestation, were the real cause of this denudation. *Zostera* is the most abundant sea-grass in south-eastern Australian estuaries. At Stewart's Point, it covers the old bed of the Macleay River for about 15 miles in water from 0 to 6 feet deep. Here, the old mouth of the river just south of Grassy Head has been closed for many years, and there is little or no water movement. The sea-grass persists in water which, in the summer, becomes too hot to walk in, and which kills *Gracilaria* and other algae. There is a similar occurrence of *Zostera* in the Crookhaven River, near Greenwell Point. In the channels of Lake Macquarie, Queen's Lake (Camden Haven), Maianbar, and Sussex Inlet, *Zostera* also covers most of the bottom, but in these cases there is a strong current of several knots. Sussex Inlet flows into George's Basin and, in the vicinity of the drop-over, as in Lake Macquarie, the *Zostera* is replaced by *Posidonia*, almost the reverse of the situation at Merimbula. In Port Stephens and Botany Bay, the dominant sea-grass on the southern shore is *Posidonia*, which extends up the estuary to Salamander Bay in the former and to Towra Point in the latter. *Zostera* is dominant on the northern shores of these estuaries. In Port Hacking, *Zostera* is dominant on both shores, except on the side of the channel near the Marine Laboratory. During the last 20 years, especially in more recent years, *Posidonia* has extended from the northern slope of the channel in Port Hacking, and has grown onto the flats, replacing *Zostera*. This may be due to the effect of man, in altering the environment by dredging, digging the flat for worms, etc., and suggests that *Posidonia* is less responsive to changes in environment than *Zostera*.

Zostera has also been observed in the unprotected Bate Bay and off Tathra, and may occur in 20 to 30 feet on sandy-mud bottom in other places. Estuarine *Zostera* is bright green when young, but later turns purple-brown owing to the development of accessory pigments while the stolons become woody. The oceanic *Zostera*, on the other hand, remains green throughout the summer, and the stolons remain succulent.

Zostera capricorni and *Z. muelleri* were found from Moreton Bay to Tuross Lake (Turlinjah), and *Z. tasmanica* from Tuross southwards. *Z. tasmanica* and, to a lesser extent, *Z. muelleri* were found at Merimbula, Mallacoota, and in the Gippsland Lakes.

The areas used for culture of the Australian oyster, *Crassostrea commercialis*, are closely associated with the *Zostera* beds, the distribution being practically that of *Z. capricorni*, though some areas are suited for spatting and others for fattening, and the *Zostera* community does not give a clue in this matter. There is no doubt, however, that the biological activity, especially that of the sulphur cycle, which occurs in the *Zostera* community plays an important part in supplying the microorganisms which the oyster requires as food and in the release of phosphate, nitrogen compounds, etc.

Acknowledgements.

Thanks are due to officers of this Division, including Prof. L. G. M. Baas Becking, for some of the data used in this paper and for helpful discussions, to Mr. L. H. Crosby for collecting material and drawing the diagrams, and Messrs. Rochford and Spencer for hydrological data.

References.

BENTHAM, A. J., 1877.—*Flora Australiensis.* Naiadae, Tribe 2, Zosteraceae: 164-182.

IMAI, T., HATANAKA, M., SATO, R., and SAKAI, R., 1951.—Ecology of Mangoku Inlet with special reference to oyster seed production. *Sci. Repts. Res. Inst. Tohoku Univ.*, D1-2: 137-156.

OSTENFELD, C. H., 1915.—On the geographical distribution of the sea-grasses. *Proc. Roy. Soc. Vict.*, 27: 179-190.

————, 1916.—Contributions to West Australian botany. I. The sea grasses of West Australia. *Dansk. Bot. Ark.*, 2: 6.

————, 1929.—A list of Australian sea-grasses. *Proc. Roy. Soc. Vict.*, 42: 1-4.

RENN, C. E., 1936.—The wasting disease of *Zostera marina*. I. A phytological investigation of the diseased plant. *Biol. Bull.*, 70: 148-158.

SETCHELL, W. A., 1933.—A preliminary survey of the species of Zostera. *Proc. Nat. Acad. Sci. Wash.*, 19: 810-817.

WINTERBOTTOM, D. C., 1917.—Marine fibre. *Sth. Aust. Dept. Chem.*, Bull. 4.

WOOD, E. J. F., 1953.—Reducing substances in *Zostera*. *Nature*, 172: 916.